Art. XIX.—*The Retinal Red and its Relation to the Sensation of Sight.*

Zur Anatomie und Physiologie der Retina. Von F. Boll. Berliner Acad. Monatsberichten, 1876. S. A. 5 Stn.

Zur Photochemie der Netzhaut. Von W. Kühne. *Über den Sehpurpur.* Von W. Kühne. Erganzungsheft zu den Verhandlungen des Naturhistorisch-medicinischen Vereins zu Heidelberg. B. 1, H. 1, 1877.

Zur Physiologie des Sehens und der Farbenempfindung. Von F. Boll. Berl. Akad. Monatsber., 11 Jan. 1877, 7 Stn.

Nachträgliche Zusätze zu dieser Mittheilung. Ebendas, 15 Feb. 3 Stn.

Der Sehpurpur beobachtet im Auge eines gehenkten Menschen. Von Prof. Schenk und Dr. Zuckerkandl. Allgemeine Wien. Zeitschrift, N. 11, 1877.

Zur Farbe der Netzhant. Von E. Fuchs. Wien. Med. Woch. N. 11, 1877.

Ueber die Verbreitung des Sehpurpurs im Menschlichen Auge. Von W. Kühne. *Weitere Beobachtungen über den Sehpurpur des Menschen.* Von W. Kühne. *Das Sehen ohne Sehpurpur.* Von W. Kühne. *Untersuchungen über den Sehpurpur.* Von A. Ewald und W. Kühne. Ergänzungsheft z. d. Verhand. des Nat.-Hist.-Med. Vereins zu Heidelberg, B. 1, H. 2, 1877.

Ophthalmoscopische Mittheilungen über den Purpur der Retina. Von Dr. Helfreich. Centralblatt f. Medic. Wissen. N. 7, 1877.

Untersuchungen über die Wahrnehmbarkeit des Sehpurpurs mit dem Ophthalmoskope. Von Dr. M. J. Dietl und Dr. Ferd. Plenk. Centralblatt für die Med. Wissen., 16, 1877.

Ueber die Diagnose des Sehpurpurs im Leben. Von Dr. E. A. Coccius. Leipzig, 3 Juni, 1877.

Ueber die Darstellung von Optogrammen im Froschauge. Von W. Kühne. *Untersuchungen über den Sehpurpur.* Von A. Ewald und W. Kühne. Ergänzungsh. z. d. Verhand. des Naturhist.-Med. Vereins zu Heidelberg, B. 1, H. 3, 1877.

Zur Anatomie und Physiologie der Retina. Von F. Boll. Arch. f. Anat. u. Physiol. Physiolog. Abth., 1877. S. 4–36.

Zur Lehre vom Lichtsinne. Von E. Hering. Wiener Sitzungsberichte, v. 66, 68, 69, 1872–1874.

Die Macula lutea, anatomisch und ophthalmoscopisch. Von Herm. Schmidt-Rimpler. Arch. f. Ophthal., xxi. 3, p. 17, 1876.

Études chimico-physiologiques sur les matières colorantes de la rétine. Par Stefano Capranica. Annales d'Oculistique, T. lxxviii, p. 144, 1877.

The theory of vision, proposed by Dr. Young about the beginning of the century and afterwards revived by Helmholtz, after holding undisputed sway for a number of years, seems at last about to be dethroned. The first effective attack was made upon it by Prof. F. Boll, of the Royal University of Rome, when he announced that the retina contained a red colour that quickly disappeared on exposure to light. The retinal red, according to Boll, is best demonstrated in the eye of a frog (*Rana temporaria*) which has been kept in a dark place for several hours. The eye is then enucleated by the aid of a feeble artificial light, cut in half, the retina taken out and laid upon its inner side upon a white surface. If now examined by a good light, the purplish-red colour of the membrane is very evident. In 10 to 20 seconds, however, the rosy tint vanishes, to be replaced by a yellowish, satiny lustre, which lasts from 30 to 60 seconds. Gradually this also disappears, and the retina becomes transparent and colourless. In this condition it remains for perhaps a quarter of an hour, but at last is found to be white and opaque. Microscopical examination shows that the red colour, as well as the yellowish tint of the second stage, is exclusively confined to the outer segments of the rods. The white, opaque appearance of the last stage is owing to the coagulation of the albuminous matters in the other layers of the retina. These peculiarities of the membrane may be found in nearly all animals which possess a retina with rod and cone layer, but last longer and are more easily observed in the amphibia and cartilaginous fishes, which have retina with large rods, than in the mammalia and bony fishes, which mostly have fine rods and cones. In the mammalia the colour-changes take place so rapidly under the influence of light that it is difficult to observe them. In crabs and cephalopods, on the other hand, the colour is especially well marked and enduring. In the frog, however, the microscope shows that all the rods are not red. A small proportion of them are of a bluish-green colour.

Dr. W. F. Norris and the writer have together repeated some of Boll's experiments and those of other investigators, as will hereafter be mentioned, and have always been successful in obtaining the above-described results with the frog's retina. In the microscopical examinations we found that the green rods were in a varying proportion of from 1 to 5 or 10 of the purplish ones, and that after the latter had become quite colourless, the former were still visible, but lighter and more bluish in colour. Indeed, the green rods apparently increased in numbers as the red ones faded.

Schenk and Zuckerkandl have also observed the retinal red in eyes removed from criminals after execution, and E. Fuchs has ascertained its existence in the eyes of still-born babes. The retinal colour has been studied, with persistent industry and a vast consumption of material, by Kühne, of Heidelberg. He has published a series of papers on the vision purple, and was probably the first to take a successful optogram. He recommends that the experiment should be tried on an atropinized and curarized rabbit, whose refraction has been previously determined by the ophthalmoscope. The subject of the picture usually taken was a window, with narrow pieces of board tacked to the frame and cross-bars so as to exclude much of the light and make an easily recognizable object. The animal was placed in the room in front of, and somewhat below, this window, at a distance of 1.75 m. After 10 minutes' exposure, the rabbit was killed and the eye extirpated in a dark room, by the aid of a sodium flame. The bulb was opened and placed in a 5 per cent. solution of alum, in order to make the retina tough enough to allow of its removal. After remaining in the alum solution for twenty-four hours, the eye was halved, the optic nerve entrance cut out with a punch, the retina detached under water and floated on to a porcelain scale, so that its outer surface should be upwards. Examined by daylight the picture was barely visible. Two minutes after the death of the animal the other eye was placed in position for receiving the image of the window, and treated as before. The picture obtained in this eye was very good. Several repetitions which we made of this experiment were uniformly unsuccessful. We always found the retinal red of the rabbit so faint as scarcely to admit of a bleached spot being seen. Indeed, Kühne says that any light strong enough to see the optogram by, is strong enough to bleach it, and subsequently recommends that the retina should be dried in an exsiccator, over sulphuric acid, for twenty-four hours before examination. In this way the colour is fixed for a time. We found this to be the case with frog's retinas.

Kühne claims to have obtained excellent optograms by using the eyes of oxen, even an hour after death. In the living frog, also, he got a good picture of a gas-flame, in front of which the animal had been induced to sit quietly for two hours. In all these cases no picture can be seen on the front of the retina, if it be examined at once and *in situ*, but only after removal from the eye is the picture visible in the back of the membrane. His remark that it is useless to attempt to take optograms unless one has plenty of time to devote to the subject, is, according to our experience, perfectly accurate.

Boll soon after published a paper in which he gave a *résumé* of the facts connected with his discovery, and mentioned that he had placed a curarized frog in such a position, behind the almost closed shutter of his window, that the thinnest possible ray of sunshine admitted between them should fall upon the animal's eyes. After ten minutes' exposure the eye was removed, and the retina found to be divided into two lateral red-coloured halves by a vertical white line.

Kühne, however, is of the opinion that an optogram is not so readily taken as this result would seem to indicate. He repeated the experiment, and ascertained that on account of the sun's apparent motion "the thinnest possible ray of sunshine" would not remain on the frog's eye for ten minutes. This difficulty, however, he met by the use of a heliostat. He then found that an exposure of twenty minutes instead of ten was necessary to produce a perceptible line, but even then it was not well defined. From our own experiments we should be disposed to consider the line described by Boll as probably accidental. Such streaks occasionally occur without obvious reason in retinas which have been exposed to strong light. Perhaps it may have been caused by the absolutely necessary use of the forceps in the removal of the membrane from the bulb. From a variety of experiments Kühne deduced the conclusion that the distance of distinct vision in the frog's eye was from 12 to 50 centimetres. The best distance is probably about 15 centimetres. He also found that if the retina is bleached quickly, in a bright light, the pigment cells adhere to it and obscure the picture. This is quite in accordance with our own experience. He therefore adopted as a test object a pane of ground glass, 45x55 centimetres, on which were pasted five strips of black paper, each 5 centimetres wide, so that the entire pane was divided into alternate translucent and opaque stripes. The curarized frog was placed on a cushion of soft black wool, its eyes made prominent by means of a paper ball in its mouth, and at the distance of 15 centimetres subjected to the mild light coming through this pane for an hour or more. The picture taken in this way covered half the retina. We repeated this experiment on a dozen different eyes, and in three cases only with satisfactory results. We found that the best subjects for the trial were very large specimens of the *Rana pipiens*, one of those we used measuring over thirteen inches in length. In a single instance only were the stripes visible on the retina in red and white. In the other two cases lines of adherent pigment marked the places where the bands of light from the window-pane had been focused, so that the image appeared reversed, in white and black.

It is probable, however, that this proportion of successful results may be considered satisfactory, for the causes of failure, such as too long or too short exposure, variations in light intensity, the difficulty of removing the retina entire and without distortion, and the troubles attendant upon the manipulation of so small an object as a frog's eye, are so numerous that even Kühne admits that he sometimes failed. Our best picture was taken after an exposure of only 45 minutes, with the sun shining on the pane. When the glass transmitted the light from a blue sky only, two hours were required to produce the optogram.

In another paper (*Zur Photochemie der Netzhaut*) Kühne discusses the effect of other agents than light upon the retinal colour. The tint is destroyed by a temperature of 100° C., by alcohol, acetic acid and by a 10 per cent. solution of soda. It is not affected by a 5 per cent. solution of common salt, strong ammonia water, 2 per cent. solution of acetic acid, alum, glycerine, ether and drying. The rays of light at the spectroscopic line D have almost no effect on the colour, and in this connection it is remarkable that only the most deeply tinted retinas, for example those from the Rana temporaria, exhibit to the observer a perceptible tinge of red when viewed by the sodium light. The colouring substance is separable from the retina by solution. Kühne puts about twenty retinas, freshly taken from frogs' eyes, into from half a gramme to one gramme of a 5 per cent. watery solution of crystallized and colourless ox-gall, in a small test tube, lets them stand for forty-eight hours, and filters. The resulting solution is perfectly clear, and of a splendid carmine-red colour. Exposed to light it becomes first orange, then yellow, at last colourless as water. In direct sunshine the bleaching is instantaneous. In diffused daylight the fading varies in rapidity according to the light intensity. The colour is perceptibly slower in disappearing in the afternoon than in the morning, or at mid-day. In this respect it is like other photochemical agents. The colouring substance probably exists in the retina in solution, for if a fresh retina is made to adhere to a glass slide, and this is exposed to light in a vertical position, the lower edge of the membrane always bleaches last; and if a row of retinas are thus placed, touching one another, the lowest retains its hue many minutes longer than the highest.

According to Boll the colour of a retina, which has been for some time in obscurity, is red, corresponding to the middle of the spectrum red. He suggests the name *Erythropsine* for the colouring matter. A. Ewald and W. Kühne made a large number of experiments (*Untersuchungen über den Sehpurpur*) to determine the precise shade of the retinal tint. They endeavoured, by means of the well-known method of Helmholtz, to find the hue which would combine with that of the retina to make white, and finally concluded that the complementary colour is pure green, that part of the solar spectrum between E and b. Analysis of the colour by means of the spectroscope was found to be unsatisfactory on account of the rapid change of tint under the action of light. They conclude, however, that the colour is purple, and name the colour-giving material *Rhodopsin.*

Under the influence of the ultra violet rays of the solar spectrum the retina becomes fluorescent. The purple rods appear blue. If bleached they look green, and still more fluorescent. The anterior layers of the retina become faintly bluish. An optogram examined by these rays shows a green picture on a blue background. Ewald and Kühne suggest the possibility of seeing an optogram *in situ* in the living human aphakial eye by means of the ophthalmoscope, using the ultra violet rays. When it is remembered, however, that their illuminating power is so slight that they cannot be seen when focussed on white paper, it must be confessed that such an examination would be accompanied with some difficulty. The ophthalmoscope, indeed, has not yet made the retinal red quite clear in the living eye. Helfreich, it is true, claims to have seen the retina of a rabbit bleach in eight minutes after section of the cervical spinal marrow, and to have then examined the other eye, which had been shaded, and found the colour of normal brightness. Boll also claims to have seen the retinal red with the ophthalmoscope, in the eye of the guinea-pig, and says that in all the mammalia the characteristic colour can be detected in this way until twelve hours after death, and thinks this fact might be of use in medico-legal cases. In his opinion there are three factors concerned in the production of the red reflex from an eye-ground viewed with the ophthalmoscope. They are: 1. The Erythropsine. 2. The blood in the choroidal vessels. 3. The red in the artificial light generally used. The last factor could of course be eliminated by using white or monochromatic light. Boll perceives a great difference in the depth and intensity of the colour of the human retina according to whether it is examined immediately after a night's sleep or late in the day, and on this bases an experiment for the subjective demonstration of the retinal red. He says that if upon first waking in the morning, in a dark room, the eyes are exposed for a moment to bright sunlight and instantly closed again, the whole field of vision will appear of a lively red, intersected with the spider's-web-like outlines of the capillaries, and marked by the macula lutea, of a ferruginous tint. All this presently fades, but the verification may be obtained several times before the colour finally becomes too faint to be distinguished. Dietl and Plenk, however, deny the possibility of seeing the retinal red with the ophthalmoscope. They say there is nothing of the kind to be seen in the frog, and this observation is amply confirmed by our own experiments. We found the image of the flame thrown on the retina to be grayish-white, and, except in the bloodvessels, no trace of colour visible. Yet the same membrane, removed from the eye, always showed the proper tint in profusion. Kühne endeavours to explain this by showing that lake-coloured fluids cannot be distinguished from black if placed on a dark background. He says that a drop of blood made lake-coloured, and placed on black paper, cannot be distinguished from a drop of ink by its side. Boll, however, claims that the red can be seen *in situ* in the frog's eye by emptying out the refractive media, and looking at the retina obliquely with the ophthalmoscope. This does not agree with our own observations, for the only colour we have been able to obtain in this way was in spots where the pigment layer had been accidentally detached, and light shown through the sclera and retina from behind. The pigment layer is so dense in the frog's eye as to render the parts covered by it perfectly opaque.

Dietl and Plenk took a rabbit, which had been kept in the dark, bound up its eyes and injected milk in one carotid while they bled from the other. The ophthalmoscope now showed the retina of a pure white. They then injected blood again until the eye-ground was red from filling of the choroidal vessels. Fifteen minutes later the retina, examined on a ground-glass slide, was found to be of a pale red. Coccius took the extirpated eye of an ox, which had been kept in the dark an hour before death, punctured it a few lines behind the cornea, and introduced a probe. Where this probe touched the retina the ophthalmoscope showed a ring of red surrounding it. If a little fold of the retina was pushed up, a streak of red appeared, which vanished again when the retina became smooth. If the retina was turned slightly round, the purple appeared in abundance. A trial of the same method in a live rabbit resulted in the same way. In this case, the retina becoming torn, effused blood obscured the eye-ground except in one place where the proper colour was plainly visible. The writer has made a number of experiments on human beings by excluding the light from one eye for several hours with a bandage, while the other eye of the same person was left free. Subsequent ophthalmoscopic examinations always failed to show any difference of tint between the two retinas.

Boll and Kühne have both investigated the effect of monochromatic light upon the retinal colour. The former found that red light intensified the hue at first, and caused it to fade very slowly. Under this illumination the microscope showed the green rods in the frog's retina becoming brighter. Yellow light affected both the red and green rods very slowly. Green light acted quickly on the red rods, but apparently caused the green ones to increase in number. Blue and violet rays acted like green. Under their influence the number of the green rods was apparently doubled, and they remained plainly visible for some time after the red ones became colourless. Ultra violet rays had no effect on the colour of the rods. Kühne also observed that the grass-green rods in the frog's retina do not bleach in green light. He placed on a screen a sufficient number of frog's retinas to cover the entire solar spectrum, and exposed them simultaneously to its influence. The bleaching commenced in greenish-yellow, and passed successively through yellowish-green, green, bluish-green, greenish-blue, blue, indigo, and violet; later through pure yellow and orange; much later through ultra violet, and finally through red. Rabbits' retinas bleached most quickly in the part of the spectrum between D and E. He found that the human retina bleached in blue to violet in 12 minutes, in green in 25 minutes, while in red the colour lasted 8 hours. Ewald and Kühne afterwards repeated the experiments on frogs' retinas with results slightly varying from the foregoing. They conclude, however, that the bleaching commences at the line E of the spectrum, and advances through green and blue to violet; then commences in yellow, and passes through orange, red, ultra violet and ultra red. Under green, however, although the retinal purple quickly changes to yellow, the complete decomposition takes place afterward more slowly. Under violet, on the contrary, the change to yellow is made very slowly; but once accomplished, it quickly fades to white. So that traces of yellow may still be seen under the green rays after all colour has disappeared under the violet. From this they infer that visible light acts on the retinal red with varying intensity, according to the colour of the rays, and that the wave lengths which most quickly change the retinal purple to retinal yellow act most slowly on this latter, while those waves which have least effect on the purple, act most quickly in changing the retinal yellow to retinal white.

The regeneration of the retinal red is not due to the circulation of the blood in the vessels. Kühne found that if a frog's eye is cut out, opened and exposed to the light, the colour is reproduced for some time as well as if the eye were in its proper place in the living body. If the posterior half of such an eye is pulled and twisted so as to throw the retina into folds, and the light is then allowed to shine upon it, the retina will be found after removal from the eye to be white where the folds were but red as to the other parts. If a frog is placed in the sun for several hours, and the eyes are then removed, the retinas will be found completely bleached; but if one of these eyes is laid in the dark for an hour, and then examined, it will have regained its colour. If the retina is carefully loosened from a lateral half of the posterior portion of a frog's eye, and a thin scale of porcelain is inserted to prevent the membrane from coming in contact with the parts beneath, and the whole is then subjected to the action of light, the raised half will be quickly bleached. If the porcelain scale is now removed, the retina replaced in position, and the eye put in the dark for a few minutes, the membrane will regain its colour. A piece of the retina may even be cut out and allowed to bleach on a plate, but if carefully replaced in position in the eye the colour is quickly restored.

Ewald and Kühne made further investigations in this direction, and found that if a retina, free from pigment cells, is held in the light until bleached, and is then placed in the dark, it will regain its colour in an hour or so. This experiment may be several times repeated with the same retina. If bleached in the living eye, however, the colour cannot be restored in this way. If the retina is removed from the eye with its pigment cells attached, the regeneration of the red is still more pronounced; but in neither of these cases is it so perfect as when the retina is laid back in the eye. We have verified most, if not all, of these results with the retina of the frog (*Rana temporaria*). Ewald and Kühne state that the solution of retinal purple in ox gall, previously mentioned, also possesses the power of regenerating its colour in the dark, and attribute this faculty to a substance which they suppose to be secreted by the pigment cells, and which they name Rhodophyllin. The pigment cells macerated in solution of gall yield a purple of peculiar intensity. Boll considers that the minute yellow globules found in the pigment layer of the frog are feeders or reservoirs of retinal red. When frogs are kept in the dark all the globules are equally coloured. But if a frog is put in the sunlight until its retina is bleached, and it is then kept in the dark for an hour, many of the globules will be found to be pale, and numbers of them quite colourless.

That the pigment cells manufacture the retinal red is supported also by anatomical considerations. It is well known that these cells send down fine filamentary processes into the interstices of the rods and cones, and these processes seem to be contractile and influenced as to their length by the amount of light thrown upon them. Boll has shown that the retina is most easily separable from the pigment layer in eyes which have been kept in the dark or in red or yellow light. It cannot be removed without tearing or without masses of pigment clinging to it from eyes which have been subjected to white, green, or blue light. When eyes of the former class have been hardened in alcohol, the microscope shows that the interstices of the rods are free from pigment; while the latter class treated in the same way exhibit cordons of pigment extending to the base of the rods at the membrana limitans externa. With regard to the structure of the rods and cones, Boll claims that the external segments are really composed of very thin plaques, of which the plaques described by Schultze (.0005 mm. thick) are merely groups containing a greater or less number. The real plaques are designated by fine transverse lines on the fresh rods, seen only by an immersion objective, and very favourable illumination. Fracture is always determined by these lines at right angles to the axis of the rods.

Kühne had no sooner taken his first optogram than he proceeded to construct a theory of vision based on his observations. He thinks that the light waves are transformed in the retina into chemical action by means of the purple which gives rise to different products for each colour. These products would, of course, affect the terminal nerve filaments each in its own manner. He believes that there may be other photo-chemical substances in the retina besides the purple. Even before the retinal red was discovered, however, Hering had called attention to some facts which seemed to indicate the existence of such a substance. The first of these facts is the phenomenon which he called *successive luminous induction*, and consists of the spontaneous formation of an areola of light around the negative image of a bright object. Another effect is seen when the line of separation between a white and a black surface is steadily regarded. At first both colours appear more intense (*simultaneous contrast*), but soon this effect disappears and after a moment each partakes of the colour of the other (*simultaneous induction*). From these facts he infers that the action of light is not limited to the retinal elements directly subjected to its rays. He was thence led to form a physico-chemical theory of vision, as the only probable one, and to suppose that the retina contained three different photo-chemical materials, which he chose to call the white-black, the yellow-blue, and the red-green substances. He thought that all the effects of light and shade, and colour might be produced by the assimilation or disassimilation of these three materials. He gave additional force to these suggestions by the remark that the hitherto received theory of retinal fatigue is disproved by the consideration that the negative image of a bright object on a dark background, developed in the closed eyes, never attains the blackness of the negative image of the same object developed on a lighter field.

But though these theories evidently point in the right direction, there are yet some facts which encourage the belief that the writing on the finger-board is not quite correct, as a guide to the road we must follow if we wish to find out the mystery of vision. Most birds, for example the pigeon and chicken, have no retinal colour. Minute red balls exist in the cones of the central, and yellow in those of the peripheral parts of their retinas; but although we exposed such retinas for an hour or more to the direct action of the sun's rays, the tint of the balls underwent apparently no change. The retinas of snakes and lizards consist entirely of cones and contain no red. Kühne was unable to find any retinal purple in man at the fovea centralis or macula lutea, and for 2 mm. around the latter the colour was very faint. The red disappears in front at from 3 to 4 mm. behind the ora serrata. At best, the rods only are coloured, the cones are colourless. Frogs, in which the retina has been bleached by exposure to sunlight, catch flies as well as ever. In such frogs the retina does not regain its colour for thirty minutes at least, but if during this time a fly commences to buzz around near them and alights anywhere within striking distance it is instantly snapped up. Coccius found that rabbits with bleached retinas saw perfectly well.

The writer has the temerity to suggest that perhaps, after all, the retinal red, as we find it, is only the excess of photo-chemical substance which in the intervals of active vision is stored up in the rods for future use. When the sight is being constantly exercised, no colour can be detected. Probably the only parts of the rods and cones capable of appreciating light are the extreme tips in contact with the pigment cells, where the retinal red is generated. The large flat ends of the rods would only be susceptible to large impressions as compared with the slender cone points. These last give us precision of detail just as we can more accurately measure a distance with compasses than with the fingers. In the eccentric parts of our retinas, where the rods much outnumber the cones, we get only general impressions of objects. But to obtain accurate definition of parts we must focus the rays on the crowded cone tips of the fovea centralis. The calculations of Volkmann showed that the smallest retinal image which could be perceived, irrespective of circles of dispersion was .0002″ in diameter; while, according to Schultz, the cone tips of the fovea are 4μ (.000148″) apart. Behind this region of distinct vision the pigment cells are more abundant than in any other part of the retina, and this insures a constant and ample supply of the visual photo-chemical substance just where it is most wanted, at the most used part of the retina. Why the red should be absorbed by the rods and not by the cones might possibly be accounted for by the broad absorbent surfaces which the former offer to the pigment cells; while the cones present an array of sharp points, more likely to repel than to attract.

It is after all not so certain that there is no retinal red at the macula lutea, for Schmidt-Rimpler reported nearly two years ago that in *perfectly fresh* human eyes, taken either from the body immediately after death or removed during life, he found the macula lutea of a dark reddish-brown colour. This spot of colour gradually grows smaller, the well-known yellowish hue taking its place. The yellow tint first forms a zone surrounding the decreasing reddish-brown spot, and encroaches on the space occupied by the latter as it contracts, so that the last speck of red is to be seen at the centre of the fovea. This red colour of the macula does not depend upon the choroidal vessels showing through, for the retina is no thinner here than elsewhere, indeed, according to Schultz, it is thicker. Besides the colour goes with the retina when it is pushed about over the choroid. Even the exceptional cases of birds and reptiles, which have no retinal red but only coloured globules in the rods and cones, become less exceptional in the light of the investigations of Capranica. He found these globules, which are of various shades, from ruby-red, through orange and yellow, to colourless, to exhibit three characteristic reactions. 1. Sulphuric acid turns them dark violet, changing to dark blue. 2. Nitric acid turns them greenish-blue, quickly becoming colourless. 3. A 0.25 per cent. solution of iodine turns them bright green, passing to greenish-blue. The coloured globules in the pigment layer of the frog's retina exhibit the same behaviour to these reagents. This leads Capranica to suppose that the only difference existing among these globules arises from the various degrees of concentration of the colouring matter. All the globules are soluble in ethylic, amylic, or methylic alcohols, in ether, chloroform, benzine, and sulphuret of carbon. These solutions are yellow, except the last, which is red. The spectroscope gives an absorption band at the line F and another between F and G. Light has more or less effect in decolourizing the solutions. Now all these tests are the same in result as those relied upon to distinguish the substance which Hoppe-Seyler and Thudicum have described under the name of *luteine*, and which is found in the yolk of eggs, in the yellow bodies of the ovaries, serum of blood, etc. It appears to stand in a parental relation to the Erythropsine of Boll, and suggests the thought that even before the eye is created the substance upon which vision depends is already in existence.

H. S. S.